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To: Mr. D.G. Comissiong
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THERMOSTAT SETBACK

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Recent literature suggests that thermostat night setback yields modest savings (which are lower if the dwelling is better insulated), can diminish comfort, is inappropriate for heat pump systems, and significantly increases peak demand of the house. It is recommended that Ontario Hydro no longer actively promote night setback.

INTRODUCTION

Popular publications give a variety of figures for the expected savings from thermostat setback strategies. As requested by Residential Marketing, recent literature was consulted to determine the proper level of such savings for the Ontario situation. Negative impacts of setback strategies were also investigated.

PERMANENT SETPOINT DECREASE

A permanent thermostat setpoint reduction (ie, 24 h/day reduction in thermostat setting) for the whole heating season will give savings of 6.5%/°C for weather and house constructions similar to those in Ontario [1, Table 5; 2, Fig. 7; 3, Appendix]. This value is basically the reciprocal of the average heating season temperature difference (expressed as a percentage) modified for weather asymmetries and the specific house degree-day reference temperature (below which the furnace is required). A house with large internal gains relative to its heat loss will have somewhat larger percentage savings.

Maintaining adequate comfort conditions for the dwelling occupants puts a limit on how low the thermostat can be set. The lower bound for typical winter clothing levels and light activity is 20°C, assuming the mean radiant temperature equals the air temperature [4, Fig. 15]. Cool walls or windows would increase the minimum acceptable thermostat setting. There thus seems to be only modest scope for energy savings by reducing the thermostat permanently. Of course, the chosen setting is a matter of personal preference, affected by the specific building envelope and heating system operating characteristics.

Low-cost strategies other than thermostat setdown can also affect energy consumption. Examples include weatherizing retrofits, zone control, isolating unused portions of the dwelling, using insulating drapes, etc.

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NIGHT SETBACK

A night setback of 5.6°C (to 15.6°C from 21.1°C) lasting 7 hours (11 p.m. to 6 a.m.) will give annual energy savings of the order of 4% to 5%, depending on the thermal integrity of the building envelope and the local climate [1, Table 3]. It is estimated that an Ontario Building Code house in Toronto will save just less than 5%, i.e. less than 1%/°C. Houses in colder climates save less in percentage terms, but more in absolute terms. Thermally improved dwellings show smaller percentage savings because the interior temperature drops more slowly when the furnace is off. In absolute terms, significantly less energy is saved for well-insulated/sealed houses. The paper concludes that, because of the modest savings anticipated, "it is not surprising that such savings have not been reliably validated by measured data" [1, p. 34].

Older references suggest savings up to twice those stated above [5, Table III; 2, Table II; 6, Table 3; 7, Tables 2 & 8; 8, Table 4]; these are discounted in this report for various reasons:

- longer (8 h) setback periods, which are deemed to affect comfort too much either in the late evening or, especially, in the morning
- assumed construction typical of the United States, but less well-insulated/sealed than Ontario dwellings
- naturally-aspirated gas furnace
- somewhat simplistic modelling, especially of the building dynamics - low assumed normal room temperature.

Promotion of setback strategies tends to subvert the comfort of our customers. Programs which depend on the resulting savings will be compromised by the occupants' natural pursuit of an acceptable indoor environment. For the elderly and others prone to hypothermia or increased susceptibility to disease with lowered temperature, a health/safety concern arises [4, p. 8.26].

There are a number of capital costs that can be associated with the provision of a setback capability in a dwelling. Although manual setback obviates the need for the retrofit of a programmable thermostat, it does not allow temperature pickup prior to arising, again with comfort implications. And the effectiveness of the setback strategy depends on twice daily occupant interaction with the heating system controls. These points are even more relevant if the more than doubled savings from including daytime setback are desired, e.g. by two-career families. Acceptably quick recovery of room temperature to normal levels requires "oversizing" (with respect to the house's design heat loss) of the furnace. In some existing installations, such excess capacity will not be available in the coldest part of the winter, and little recovery will occur. Larger furnaces increase the difficulties with cold load pickup after outages on the electrical distribution system. For recovery within one hour from a 5.6°C setback, 40% to 100% oversizing is required, depending in part on the thermal integrity of the building envelope [1, p. 33; 2, Fig. 8; 6, Fig. 6; 7, Table 2]. The last reference also indicates increasing room temperature swings with increasing "overcapacity", again affecting comfort.

Because savings are largely negated by the energy required to restore normal temperatures, deep setbacks (e.g. 11.1°C down) and setbacks during the coldest part of the winter save very little [1, p. 33]. Customers should be made aware of these counter-intuitive results. Setback control should thus be suspended on the chilliest nights; recovery difficulties, increased comfort concerns and power demand effects on the electrical distribution system are also avoided. The latter topic is further discussed below.

There are a few indirect implications of setback strategies. With the furnace blower in forced warm air systems normally set to run only when heat is required, air circulation (which aids local ventilation) stops for many hours while room temperature decreases to the lower setpoint. Continuous run operation cures this problem, but with possible noise implications. Cooler room temperatures during setback will more quickly cool off the hot water in the distribution pipes, a small effect. The water heater standby loss will be increased, requiring more energy to maintain the tank temperature during setback. The internal temperatures in refrigerators and freezers may be affected by the changing ambient temperature.

POWER DEMAND

Figure 1 compares the coldest-day load profile for a typical Ontario house with and without night setback. The dramatic 65% peak demand increase and the five hour excursion above the normal peak for the setback situation indicates a serious problem for the local electrical distribution system. Diversification of individual house loads due to random furnace on-times among large groups of houses would be significantly compromised by common pickup times around the usual breakfast hour. Even load management initiatives for the generation system (shifting load out of the 7 a.m. to 11 p.m. period) may need to account for these changes in demand profile with setback. (One caution: the continuing location of the setback line above the normal line for most of the day may be an artifice of the original setback option modeled in the reference, which included some daytime zone control; further research on this point is warranted.)

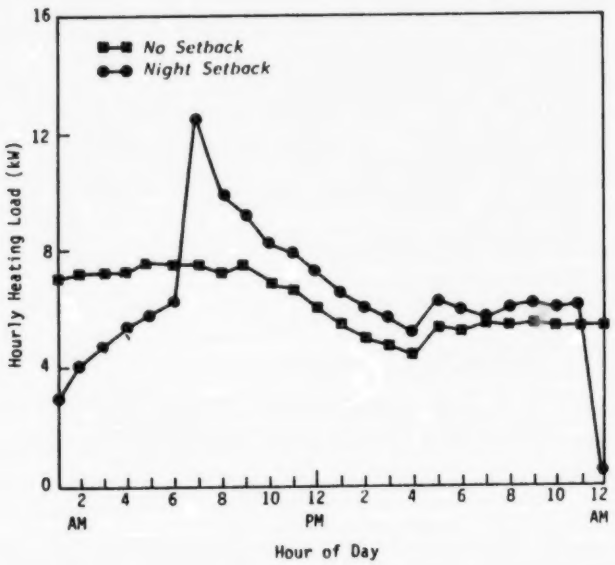

FIGURE 1
HOURLY LOADS ON COLDEST DAY OF THE YEAR
FOR A TYPICAL HOUSE IN ONTARIO
[ADAPTED FROM REF 1, FIG 2]

HEAT PUMPS

Heating systems incorporating heat pumps present a special case concerning the effect of thermostat setback. Because the backup resistance heater is used in the recovery process, negating the COP-based savings of heat pump operation, setback savings are less than for resistance-only heating systems, except for small setbacks [2, p. 325; 8, Table 4]. The replacement of heat pump operation with straight resistance heating during recovery also adversely affects the peak demand characteristics of the house [8, Fig. 6-8]. Although the details of the analysis in reference 8 are too liberal (as discussed previously), they show that savings for large setbacks (5.6°C) are no larger, and can be less than those for more modest setbacks (2.2°C) [8, Fig. 1]. Also, the larger the backup resistance heater, the lower the savings [8, Fig. 2]. Thus good savings and rapid recovery (for comfort) are diametrically opposed for heat pump systems. Net losses from setback can arise when the outdoor temperature is close to the system balance temperature (below which backup is required) [8, Table 5]. Control strategies to start recovery early on heat pump alone could alleviate the energy waste from the extra use of the backup, but with reduced savings potential because of the shorter setback period. The modest savings might not justify the added cost of the more sophisticated controls. Reference 8 sums up: "we do not recommend the general use of thermostat setback with residential air-source heat pump systems at the present time" [8, p. 357].

Permanent thermostat setpoint reductions for heat pump systems give slightly larger savings than resistance-only systems, because of the resulting shift in the system balance temperature [8, Table 2].

CONCLUSIONS

1. Permanently reducing the thermostat setting saves about 6.5%/°C on the energy bill for typical Ontario houses. The scope for large savings is limited by comfort concerns.

2. The energy savings from thermostat night setback are modest, less than 1%/°C, in typical Ontario houses.

3. Houses that are better insulated and sealed show lower savings from night setback strategies.

4. For comfort on awakening after night setback, pickup must begin well before. This decreases savings and requires a programmable thermostat.

5. Night setback with a heat pump system gives small savings, even negative ones for deep setback.

6. Recovery from night setback for an all-electric heating system imposes a significant extra peak demand on the electrical distribution system.

RECOMMENDATION

Ontario Hydro should not actively promote thermostat night setback strategies, and may wish to inform its customers of some of the negative aspects of such actions, especially for heat pump systems.

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REFERENCES

1. J. Ingersoll and J. Huang, "Heating Energy Use Management in Residential Buildings by Temperature Control", Energy and Buildings, Vol. 8, No. 1, February 1985, p. 27-35.

2. L.W. Nelson and J.W. MacArthur, "Energy Savings Through Thermostat Setback", ASHRAE Transactions, Vol. 84, Part 2, 1978, p. 319-334; (also ASHRAE Journal, September 1978, p. 49-54).

3. S. Mastoris, "Energy Conservation by Improving the Performance of Electric Heating Thermostats", Ontario Hydro Research Division Report No. 77-86-K, February 17, 1977.

4. ASHRAE Handbook 1985 Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia, 1985, Chapter 8.

5. L.W. Nelson, "Reducing Fuel Consumption with Night Setback", ASHRAE Journal, August 1973, p. 41-49.

6. K. Koenig, "Gas Furnace Size Requirements for Residential Heating Using Thermostat Night Setback", ASHRAE Transactions, Vol. 84, Part 2, 1978, p. 335-351.

7. D.W. Locklin, K.E. Herold, R.D. Fischer, F.E. Jakob and R.A. Cudnik, "Supplemental Information from SP43 Evaluation of System Options for Residential Forced-Air Heating", preprint of paper NT-87-20-4, ASHRAE Transactions, Vol. 93, Part 2, 1987.

8. C.E. Bullock, "Energy Savings Through Thermostat Setback with Residential Heat Pumps", ASHRAE Transactions, Vol. 84, Part 2, 1978, p. 352-363; (also "Thermostat Setback & Residential Heat Pumps", ASHRAE Journal, September 1978, p. 38-43).

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